FUNCTIONAL ANATOMY OF THE SPINE BY AVICENNA IN HIS ELEVENTH CENTURY TREATISE AL-QANUN FI AL-TIBB (THE CANONS OF MEDICINE)

The history of spinal surgery is an important part of the spine-related sciences. The development of treatment strategies for spine-related disorders is acquired from the Western literature. In this article, an Eastern physician, Ibn Sina, who is known as Avicenna in the West, and his treatise, Al-Qanun fi al-Tibb (the Canons of Medicine), are presented. Eight chapters of this book regarding the functional neuroanatomy of the spine were reviewed and are presented to give insight into the development of the understanding of spinal anatomy and biomechanics.

Key Words: Al-Qanun fi al-Tibb, Avicenna, The Canons of Medicine, History, Spine

The scientific studies regarding the clinical biomechanics of the human spine began in the second half of the past century. However, the anatomy of the human spine has been studied since ancient Greco-Roman times. Most anatomic knowledge during the Medieval period (the “dark ages”) was based on preliminary studies on animals and, less commonly, on humans. The Galenist school affected anatomy for several centuries. Avicenna (980–1037) (Fig. 1) reviewed all the previous anatomic literature and added his own observations (2). A great clinician and teacher, he was one of the most important scientists of the ancient world (Figs. 2 and 3). He combined common anatomic knowledge on spinal anatomy with some biomechanical explanations. This study presents Avicenna, his treatise Al-Qanun fi al-Tibb (the Canons of Medicine), and its spinal anatomy-related chapters.

AL-QANUN FI AL-TIBB (THE CANONS OF MEDICINE)

Avicenna’s contribution to mankind and medicine is his famous book Al-Qanun fi al-Tibb (the Canons of Medicine) (3–6). The Canon systematically reviews all the medical knowledge studied by the ancient Greek and Muslim scientists. Avicenna stated, “I believe that at the beginning, the pupils should learn the general principles of medicine, both in theory and in practice. Analysis of diseases which affect different organs will precede the methods of keeping these organs in sound health. To satisfy this, we must first study the anatomy of these organs.”
The *Canon* was translated into Latin by Gerard of Cremona in the 12th century. Because of its systematic approach and its superiority to Galen’s medical book, the *Canon* became the textbook for medical education in the European schools for more than 6 centuries (1). The *Canon* was regarded as the principal medical text until 1650, and it is the second most published book (after the Bible) since the invention of publishing. The *Canon* studies drugs, physiology, pathology, and pharmacology.

Avicenna made several contributions to anatomy, and his *Canon* contains a number of his anatomic findings, many of which are accepted today. In the *Canon of Medicine*, there are several chapters of anatomy in the first volume of the book. In addition, the discussions of anatomy are scattered throughout the huge encyclopedia, with the anatomy of a particular organ being discussed in the section concerned with diseases particular to that organ. These anatomic sections of the *Canon* were often copied out and compiled as separate treatises (Fig. 4). This study summarizes the spinal anatomy-related sections of this treatise (i.e., Chapters 6 through 13).

### CHAPTER 6: FUNCTIONS OF THE SPINE

The spine has four functions. First, it serves as a channel for the spinal cord, which is of vital importance to animals. Spinal cord function is explained in the spinal cord chapter. In this chapter, emphasis is placed on the brain and nerves. If all the nerves exited directly from the brain, the brain would be bigger. For example, nerves innervating the hands and feet would travel a longer distance and, thus, would be more prone to injury; they would also become less able to innervate the big muscles of the thigh and the calf. Therefore, God created the spinal cord below the brain. The spinal cord is like a channel coming out of a fountain in the way that nerves emerge from both sides and go down, thus putting the organs
closer to the brain. That is why God placed the spinal cord into a hard bony channel called the spine to protect it from injury. Second, the spine protects the organs close to itself. That is why it has bony projections and spikes. Third, the spine is like the axle of a coach. It forms the structure of the bony skeleton. Finally, in humans, the spine is a powerful and unchanging cushion during standing erect and bending to the sides. The back is formed by vertebrae allowing these movements. The joints between these vertebrae are neither too loose to move freely, nor too rigid to form a straight block.

CHAPTER SEVEN: VERTEBRAE

The vertebrae are hollow bones to allow the spinal cord to pass through them. Each vertebra has two superior and two inferior side projections to form joints. There may also be eight projections. The joint projection of one vertebra faces a joint projection of an adjacent vertebra. These projections also protect the vertebra from crashes and injuries. Longitudinally and transversely, vertebrae are covered with strong fibers. These are united superiorly and inferiorly throughout the length of the spine. A vertebra has transverse processes at both sides and spinous processes posteriorly so it can protect the nerves and vessels like longitudinal muscles. The transverse process of a thoracic vertebra has smooth, shiny facets forming joints with tubercles on the ribs. Some transverse processes have two heads, and they seem to have two eminences. However, this is only seen in cervical vertebrae. In addition to the spinal canal, there are foramina and notches to allow for the passage of nerves and vessels. Some foramina are in the bony vertebrae, and some are formed on the joint surfaces by crescents on both vertebrae. These foramina may be large or small, and they are found up and down on both sides of the vertebra. These are placed laterally, because posteriorly there are no structures to protect the passing structures and anteriorly they are prone to injury by the spikes placed anteriorly. The spine is empowered by the ligaments and tendons. Ligaments facilitate movement and lubricate the muscles. These ligaments also protect the joints. The anterior longitudinal ligament is stronger than the posterior one because anterior movement is needed more than posterior movement.

Posterior to the spine, there is a space formed by the elongation of the fibrous tissue. This space has humidity to facilitate the freshness of the spine. The spine is formed by many vertebrae so it can move easily. If the spine was formed by a single bone, it would have been difficult to establish movement.

CHAPTER EIGHT: CERVICAL SPINE AND ITS FUNCTION

The neck is designed to form a space for the trachea. Cervical vertebrae are placed on top of each other, and the smallest vertebra occupies the top. If the object at the top has mobility, it must always be lighter than the objects supporting it. The spinal cord is thicker at the top; it gets thinner as it goes down and gives out nerves. The width of the atlas is less than the others, but it has more mobility and density to gain equilibrium. Cervical vertebrae have short processes instead of long processes, which are more prone to injury. Because of their mobility, cervical vertebrae have longer transverse processes. These vertebrae carry less weight than thoracic vertebrae, so their bodies are weaker but their joints have more mobility. The weakness of the spinous processes of cervical vertebrae is balanced by the organization of a network of muscles, vessels, and nerves. Superior and inferior facets of cervical vertebrae are smaller, and their ligaments are looser. The neural foramina are placed between neighboring vertebral bodies.

Cervical Vertebrae

There are seven cervical vertebrae. Their number, size, and length are designed in an obvious pattern. Except for the C1 vertebra, all the cervical vertebrae have spinous, transverse, superior, and inferior processes. Each transverse process has a transverse foramen. The atlas and axis have different characteristics. Movements of the head to the left and right are facilitated by the joints between the head and the first cervical vertebra. However, anterior and posterior movements of the head are facilitated by the joint between the head and the C2 vertebra. The joint between the head and the C1 vertebra is formed by the superior articular facet of the C1 and occipital condyles. If one condyle elevates the head, the other bends it. The second cervical vertebra has no superior articular face; instead, it has an odontoid process situated in the spinal canal. The spinal canal has a broader anteroposterior diameter to support the odontoid process. The spinal cord is protected by strong ligaments and fibrous bands around the odontoid process. The odontoid process enters the foramen magnum and forms the joint facilitating anterior and posterior movements of the head.

The odontoid process has two functions. First, it is an efficient protector. Second, it prevents displacement of the thinner first cervical vertebra. The C1 vertebra is well protected by the C2 vertebra. Therefore, it does not need an extra process. The exit of spinal nerves is a different aspect of the first cervical vertebra. The nerves do not emerge from the intervertebral foramina; instead, they emerge dorsally on the bone. If nerves emerged laterally, they would be damaged by the lateral movements of the head. Because of the movement characteristics of the first cervical vertebra, the nerves cannot exit on its anterior or posterior aspect; the best place for nerve emergence is the posterolateral face. The foramen is smaller, so the spinal nerves are thinner.

On the second cervical vertebra, nerves do not emerge on the superior surface because there is a possible risk of injury from the movements of the first cervical vertebra. Also, it is not possible for these nerves to emerge laterally and posteriorly. If they did so, the first and second cervical spinal nerves would be so close that they would blend with each other and become weaker. The best place for the nerves is lateral to the joint processes. During the anteroposterior and lateral move-
ments of the head, the first and second cervical vertebrae act as a single bone and move together.

CHAPTER NINE: THE THORACIC SPINE AND ITS FUNCTIONS

Costae make joints with thoracic vertebrae and form a cage around the lungs. The first 11 thoracic vertebrae have both spinal and transverse processes. However, the twelfth thoracic vertebra has no transverse process. The transverse processes of the thoracic vertebrae are placed close to the vital organs, and they are of varying sizes and shapes. These transverse processes on the superior seven thoracic vertebrae are larger and thicker to protect the heart. The costal joint facets on the transverse process of the ninth thoracic vertebra are shorter and broader. These facets are the same size as the costal joint facets. The spinous processes of the superior thoracic vertebrae face superiorly. The spinous process of the tenth thoracic vertebra is straight and thick (it does not face superiorly or inferiorly). The joint facets of the tenth thoracic vertebra are smooth, and there are no tubercles. Below the tenth thoracic vertebra, the joint facets are broad and invaginated to form joints with the superior vertebral bodies. Their spinous processes look superiorly. The twelfth thoracic vertebra has no transverse process because the twelfth rib has no joint projection to the twelfth vertebra. The twelfth rib has strong connections with muscles and ligaments, and it does not need this joint with the vertebra.

Lumbar vertebrae should be big and strong to carry the superior vertebrae. Therefore, these vertebrae have a greater joint area and more projections. The last thoracic and the first lumbar vertebra are similar. The first lumbar vertebra has large joint projections to compensate for the absence of transverse processes. Starting from the cervical spine, the spinal canal becomes narrower. The spinal canal is quite narrow in the inferior thoracic and lumbar spine. There is not enough space for the spinal cord. The spinal canal in the lumbar and sacral spine allows for the passage of the lumbar and sacral nerves.

CHAPTER TEN: THE LUMBAR SPINE

There are five lumbar vertebrae. They have large spinous and transverse processes. Joining the sacrum, lumbar vertebrae form the foundation of the spine and cushion it. In addition, they support the pubis and allow the emerging nerves to exit to the legs.

CHAPTER ELEVEN: THE SACRUM

There are three vertebrae in the sacrum. These are rigid and strong. They have large transverse processes. The foramina for the emerging nerve roots are placed dorsally.

CHAPTER TWELVE: THE COCCYX

The coccyx is formed by three vertebrae that have no projections. The nerves are small like the cervical nerves, and they emerge between the vertebral bodies. Only a single nerve emerges from the tip of the third vertebra of the coccyx.

CHAPTER THIRTEEN: FINAL CONSIDERATIONS REGARDING THE FUNCTION OF THE SPINE

In explaining the vertebrae of the spine, its function is also evaluated. Vertebral bodies of the spine are constructed as a cylindrical column in the best design to act as a single body to prevent injury. Superior vertebral spinous processes face inferiorly. Inferior vertebral spinous processes face superiority. The spinous process of the tenth thoracic vertebra is straight and horizontal, and this central position is not related to vertebral number; instead, it is related to the vertebral length. During the movement of the spine to the left and the right, it also turns.

DISCUSSION

The modern era in human anatomy started in the 16th century with the studies of Andreas Vesalius (1514–1564). The earliest anatomic studies, however, were performed by Alcmaeon of Crotona (500 BC) on animals and by Herophilus and Erasistratus of Alexandria (300 BC), who made the first systematic anatomic dissections on humans. After 150 BC, human dissections were prohibited for religious and ethical reasons. The prohibition was enforced by Rome. In the 2nd century AD, Galen made several anatomic dissections on animals (mostly Barbary apes and pigs). Galenist anatomy, with its correct and incorrect aspects, influenced anatomists for several centuries.

The anatomic information written by Avicenna in the Canon reflects a review of the treatises written by the earlier Greco-Roman authors and Galen and Avicenna’s own observations and considerations. It is not known, however, how much of Avicenna’s anatomic knowledge is original and is based on his own studies. Because of the prohibition regarding anatomic dissections on humans in Islamic cultures, Avicenna’s anatomic considerations might be based on his clinical observations.

Although there are several studies on Avicenna and his Canon, this is the first study focusing on the spinal anatomy-related chapters of this treatise. A careful analysis of these eight chapters shows the level of knowledge regarding the biomechanical anatomy of the spine in the 11th century.

In his treatise, Avicenna tried to find explanations for the anatomic features of the vertebrae and the spinal region. He emphasized that the shape and the size of any given vertebra is determined by its regional function. Therefore, he classified the spine into the following segments, similar to the classification system used today: cervical, thoracic, lumbar, sacral,
and coccygeal. Then, he described the anatomic features of the elements of the vertebrae in each region.

A review of the Canon reveals some errors in his anatomic considerations, particularly regarding the anatomy of C2, T12, and the number of sacral vertebrae. However, despite these anatomic errors, Avicenna described the biomechanical features of the vertebrae and the spine almost correctly. He described the flexion, extension, and lateral bending aspects of the motion segments (Chapters 8 and 9), as well as the coupling phenomenon of the thoracolumbar spine (Chapter 13).

The most interesting opinions of Avicenna are on the biomechanics of the craniovertebral junction. Avicenna described the different characteristics of the atlas and the axis. He reported that “the head-atlas motion segment is responsible for lateral bending, whereas the C0 to C2 segment makes anteroposterior motion possible. One condyle elevates the head, the other bends it.” According to Avicenna “the odontoid process has two functions: it protects and it prevents the displacement of the thinner first cervical vertebra. During the anteroposterior and lateral movements of the head, C1 and C2 vertebrae act as a single bone and move together.”

The similarities between some parts of Avicenna’s Canon and our current biomechanical knowledge are surprising. In addition, the presented chapters of the Canon reveal that an understanding of spinal biomechanics was a necessity even 1000 years ago.

REFERENCES


COMMENTS

The effort expended by these authors is immense. The article gives a clear explanation of the anatomy and biomechanics of the spine. Four centuries after the writing of Ibn Sina (1, 2), I do not think much needs to be added. The detailed anatomic description, at a time when dissection of bodies was not accepted because of religious beliefs, suggests that his knowledge was obtained from the large number of surgical operations he performed.

I am sure the reader will need more details about Ibn Sina, “the Persian physician.” He was born in the village of Afshama in Persia, and his family moved to Bukhara when he was 5 years old. He was a gifted child with an exceptional memory. He practiced self-education and was a master in Islamic law and medicine. His interest in medicine appeared at the age of 17. He served various rulers during his life as a government official and was a physician at the age of 20. At the same time, he was a free-thinking politician, which involved him in conflicts with government officials, forcing him to move from one place to another or to hide for some period of time, and he was even imprisoned.

As a Persian physician, he was a remarkable person in his time. He completed 45 books on philosophy, medicine, geometry, astronomy, theology, metaphysics, and poetry. His encyclopedia of philosophy, Ashshifa (The Recovery), encompasses logic, philosophy, metaphysics, and natural science. Some of his books were translated into Latin, Hebrew, and, in 1953, English.

The Canons of Medicine was one of the earliest Arabic books to see print. The book was taken as a reference in medicine in Western universities until the 17th century.

His readings in the book of Aristotle on metaphysics, facilitated by the philosopher Al Farabi, allowed him to understand the nature and invention of scientific facts. His description of intracranial anatomy was based on Galenic studies. He divided the brain into the medulla and cortex. He performed burr hole trephination with the patient under opium anesthesia, with numerous students watching him during surgery. He dealt with all the branches of medicine, including cancer, and advised early radical surgery for the best results. He also stressed the relation of nervous tension and psychological effects leading to peptic ulcer and irritable colon.

In addition to his clinical examination of patients, he always confirmed the diagnosis by examining the urine, stools, and pulse. Ibn Sina included love as a disease, “love sickness,” because it always has physical symptoms, and he explained how to diagnose it by counting the pulse during the recitation of different names, including that of the lover, finding that the pulse rate rises with tachycardia when the name of the beloved is mentioned. In his bedside observation, he could differentiate between pneumonia and acute meningitis and the facial palsy caused by an intracranial or peripheral lesion. He was the first to diagnose and treat ankylostomiasis; he called it roundworm.

One of his efforts was the proper explanation of the production of a boy or a girl child and that it depends on the father and not the mother. His methodology in the academic study of medicine was to start by studying anatomy and physiology. This talented genius and open-minded sheik was a man of excellence in his time, particularly in medicine at a time when there was no computed tomography or magnetic resonance imaging.

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This is a very welcome brief historical note indicating that Avicenna devoted a significant degree of time and effort to problems of the spine. It is a delight to read this historical vignette.

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The Eastern physician Ibn Sina, known as Avicenna, was a very important scientist who lived between the years AD 980 and 1037. His anatomic works, especially on spine, were written with a surgeon’s consciousness, because he was a surgeon. The origin of his anatomic knowledge is not known, because anatomic dissection on human bodies was prohibited during Avicenna’s era. However, his orientation and descriptions of the spinal anatomy at that period are exceptional.

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In the present-day literature, there is very little in the English language on the original writings of Avicenna and his classic work titled The Canons of Medicine. The authors of this article have provided an English translation from the original Arabic of the various sections dealing with the anatomy and function of the human spine. After one reads these various sections, it becomes quite clear that Avicenna had a most remarkable grasp of the anatomy of the spine and some of its biomechanical aspects. An intriguing question that arises, and one not easily answered, is how many of the original dissections were performed by Avicenna himself, versus what he adapted from the earlier Greco-Roman writers. The authors do allude to this in the text, but it would be wonderful if more information might be provided with some further research. There has been much discussion in the historical literature about how the Koran forbids human dissection, yet I remember from years of reading various sources that there were exceptions to this edict by some of the early anatomists. This last thought leads naturally to Avicenna and the question of whether he actually performed human dissections. It would appear that he did.

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Left, Egas Moniz in 1949 (courtesy of Antonio vas Carneiro, M.D., Ph.D., University of Lisbon School of Medicine, Lisbon, Portugal). Right, the “core operation.” Prefrontal leukotomy was performed by Egas Moniz and Almeida Lima. The leukotome was inserted into the brain at the approximate angles shown; when the leukotome was in place, the wire was extended and the handle rotated. In the first leukotomy, one “core” was cut on each side of the brain. In subsequent operations, progressively more “cores” were cut. The right side of the figure depicts a horizontal slice of the brain (parallel to the top of the cranium) with Moniz’ estimate (without evidence) of the extent of damage (drawn by R. Spencer Phippen, in Valenstein ES: Great and Desperate Cures: The Rise and Decline of Psychosurgery and Other Radical Treatments for Mental Illness. New York, Basic Books, Inc., Publishers, 1986).